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Revisiting the environmental Kuznets curve in a global economy

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ABSTRACT

The present study deals with an empirical investigation between CO_2 emissions, energy intensity, economic growth and globalization using annual data over the period of 1970–2010 for Turkish economy. We applied unit root test and cointegration approach in the presence of structural breaks. The direction of causality between the variables is investigated by applying the VECM Granger causality approach. Our results confirmed the existence of cointegration between the series. The empirical evidence reported that energy intensity and economic growth (globalization) increase (condense) CO_2 emissions. The results also validated the presence of environmental Kuznets curve (EKC). The causality analysis shows bidirectional causality between economic growth and CO_2 emissions. This implies that economic growth can be boosted at the cost of environment.

Contents

1. Introduction

Turkey has experienced a significant rise in economic growth, energy consumption and carbon emissions during the last two decades. Turkey is a candidate for full membership of European Union (EU) and therefore is likely to face significant pressures from EU during negotiations to introduce its national plan on climate change and global warming along with specific emissions targets [1]. Turkey is one of the important countries which have a high carbon emissions and economic growth in the world. The reports of World Bank and UNDP indicate that CO_2 emissions would rise more than six-fold by the end of 2025 rather than 1990s, so it is a great challenge for Turkey to achieve both the targets of high economic growth and less CO_2 emissions at the same time.

The present study contributes in energy economics by four ways: (i), we augmented the CO_2 emissions function by incorporating globalization as a potential determinant of energy intensity, economic growth and CO_2 emissions; (ii) Zivot–Andrews [2] unit root test has been applied in determining integrating order of the variables; (iii) Gregory–Hansen structural break cointegration test is used to examine the robustness of long run relationship between the variables; and (iv) direction of causal relation is investigated by applying the VECM Granger causality test. Our findings confirm the existence of long run relationship between

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economic growth, energy intensity, globalization and CO_2 emissions. We find that the EKC is validated in case of Turkey. Moreover, energy intensity is a, major contributor to CO_2 emissions, and globalization improves the environmental quality. The feedback effect exists between economic growth and CO_2 emissions. Energy intensity and globalization Granger cause CO_2 emissions.

The rest of the paper is organized as follows: Section 2 presents review of literature; Section 3 provides data information, modeling and estimation strategy; result interpretations are in Section 4 and Section 5 deals with conclusion and policy implications.

2. Literature review

In 1991, Grossman and Krueger started the debate of environmental Kuznets curve (EKC) which explained the relationship between environmental pollution and economic growth i.e. inverted U-shaped relationship. Later on, a series of debate has started by investigating the relationship between environmental pollution and economic development. Johansson and Kriström [3] noted that the literature on EKC is not enough and this topic needs more empirical investigation. But Stern [4] argued the issues of EKC should be revisited by using new models and new decompositions with different panels and time series data sets. Similarly, Wagner [5] pointed out that the data on per capita CO_2 emissions and per capita GDP are not stationary in time series framework and this problem is not sufficiently addressed in literature. Therefore, many dimensions of EKC are available for further empirical investigation.

Existing literature provides two strands of relationship between energy consumption and energy emissions i.e. economic growth and energy consumption and, economic growth and CO_2 emissions in case of Turkey (see [6], for literature survey on energy-growth nexus). For example, Altinaya and Karagol [7] investigated the direction of causality between energy consumption and economic growth. They applied unit root test to examine stationarity properties of the variables. The Hsiao Granger causality was applied using time series data over the period 1950–2000. Their empirical exercise reported the neutral effect between economic growth and energy consumption. Lise and Montfort [8] probed the relationship between gross domestic product and energy consumption using annual data for the period of 1970–2003. The Granger causality analysis found unidirectional causality running from economic growth to energy consumption.

Soytas and Sari [9] analyzed the relationship between energy consumption in industrial and manufacturing sectors using multivariate model by incorporating capital and labor in production function. Their results indicated cointegration between the variables for long run relationship. The results of vector error correction (VECM) model reveal that there is unidirectional causality running from energy consumption to manufacturing GDP. Furthermore, the results of variance decomposition and generalized impulse response analysis confirmed that energy consumption is an important factor of manufacturing GDP. This implies that utilization of energy saving modes and energy efficiency technology may enhance manufacturing production in Turkey. Similarly, Jober and Karanfil [10] reinvestigated the relationship between energy consumption and economic growth at aggregate level and at sectoral industry level. Their results reported that there is no causality between both variables at aggregate level as well as sectoral level.

Erdal et al. [11] used the data over the period of 1970–2006 to reexamine the relationship between energy consumption and real GNP. They applied augmented Dickey–Fuller (ADF) and Philips–Perron (PP) unit root tests to test stationarity properties of both variables and Johansen cointegration for long run as well as Granger causality test for pair-wise causality. The empirical exercise reported the cointegration between energy consumption and real GNP. The causality analysis revealed feedback effect implying that economic growth and energy consumption are interdependent. This suggests that any negative energy shock will put negative effect on economic growth of Turkey. Kaplan et al. [12] reexamined the causal relationship between economic growth and energy consumption over the period 1971–2006 using supply and demand side models. Their results found long run relationship as cointegration is found between the series. The causality analysis found feedback effect between economic growth and energy consumption. This shows that for achieving high level of economic growth more energy is needed and supply of energy further enhances economic growth, implying that any shock which occurred in supply of energy puts a negative impact on economic growth.

The second strand deals with the relationship between economic growth and CO_2 emissions such as, Akbostanci et al. [13] tested the direction of causality between income and environmental degradation using various stages of economic development using PM_{10} and SO_2 measures of environmental degradation. They used data of 58 provinces of Turkey over the period 1968–2003. Their empirical results unveiled that CO_2 emissions and income have long run relationship but inverted U-shaped relationship is found when they SO_2 and PM_{10} are used as measures of environmental degradation. The results do not support EKC hypothesis based on income and environmental degradation nexus.

Halicioglu [14] augmented CO_2 emissions function by incorporating trade to investigate the causal relationship between income,

Table 1
Summary of studies on Turkey.

No.	Authors	Time period	Variables	Cointegration	EKC hypothesis
1.	Altinaya and Karagol [7]	1950–2000	GDP per capita, energy consumption	–	–
2.	Lisea [19]	1980–2003	GNP growth, CO_2 emissions	–	–
3.	Lise and Montfort [8]	1970–2003	GDP per capita, energy consumption	Yes	–
4.	Soytas and Sari [9]	1968–2002	Energy consumption, industrial value-added	Yes	–
5.	Jober and Karanfil [10]	1960–2003	GNP growth, energy consumption	–	–
6.	Erdal et al. [11]	1970–2006	Energy consumption, GNP per capita	Yes	–
7.	Akbostanci et al. [13]	1992–2001, 1968–2003	GDP per capita, CO_2 emissions	Yes	EKC does not exist
8.	Halicioglu [14]	1960–2005	Income, CO_2 emissions, energy consumption, trade openness	Yes	–
9.	Soytas and Sari [15]	1960–2000	GNP, CO_2 emission, energy consumption	Yes	–
10.	Ozturk and Acaravci [1]	1968–2005	GNP per capita, CO_2 emissions, energy consumption, employment	Yes	EKC does not exist
11.	Jobert et al. [17]	1970–2008	GNP per capita, CO_2emissions, energy consumption	–	EKC exists
12.	Kaplan et al. [12]	1971–2006	GNP per capita, energy consumption	Yes	–
13.	Joberta and Karanfil [18]	1971–2008	Energy consumption, CO_2 emissions, real GDP per capita	–	EKC exists
14.	Ozturk et al. [20]	1960–2006	GNP growth, energy consumption	Yes	–

CO_2 emissions and energy consumption for the period 1960–2005. Halicioglu found cointegration by applying the ARDL bounds testing approach to cointegration. The results showed that GDP is highly significant among other variables of the model in explaining CO_2 emissions in case of Turkey. Soytas and Sari [15] reexamined the relationship between economic growth, CO_2 emissions and energy by incorporating capital formation and labor as potential determinants of economic growth and CO_2 emissions. Their results exposed that CO_2 emissions Granger cause energy consumption but same and vice versa which implies that by reducing CO_2 emissions, Turkey may not forgo economic growth. Kaygusuz [16] investigated the electricity and energy demand functions and their empirical exercise found that rapid energy consumption and energy production are linked with environmental issues at national level as a rise in energy consumption (electricity consumption) increases CO_2 emissions.

Ozturk and Acaravci [1] reinvestigated the cointegration and causality between economic growth, CO_2 emissions and energy consumption by incorporating employment using time series data over the period 1968–2005. Their results indicated the existence of cointegration between the variables and found that income elasticity of CO_2 emissions is inelastic (−0.606) but income elasticity of energy consumptions is more elastic (1.375). Their analysis could not provide the empirical validation of the EKC hypothesis. The causality analysis found neutral effect between energy consumption and economic growth, economic growth and CO_2 emissions and, energy consumption and CO_2 emissions. This implies that the adoption of energy conservation has no adverse effect on growth rate of real GDP. Jobert et al. [17] probed the relationship between economic growth, CO_2 emissions and energy consumption by applying Bayesian empirical model. The study used time series data of 50 countries including Turkey over the period of 1970–2008. Their empirical analysis reported that existence of the EKC is sensitive with respect to countries but EKC exists in case of Turkey. Joberta and Karanfil [18] used cross-country data including Turkey to test the validation of EKC and found the existence of EKC before 1980. The threshold level of income is rising which was reported as 10,000 in early 1980 and 20,000 in 2008 (Table 1).

The 21st century has increased the internationalization among the world economies and countries are more closely linked with each other economically, politically and culturally. Globalization which is based on economics facilitates and helps in the promotion of division of labor and increases the comparative advantage of different nations. Globalization improves the total factor productivity by increasing trade activity but also boosts economic activity via foreign direct investment and transfer of advanced technology from developed countries to developing nations. Globalization also provides investment opportunities including foreign direct investment and develops the financial markets. Globalization directly enhances trade and then economic growth while indirectly, it promotes investment opportunities not only in the form of domestic investment but also in foreign investment, which not only influences energy demand but also influences the environment.

Various researchers have used different measures of globalization to examine its impact on environmental degradation. For instance, Grossman and Krueger [21] investigated the environmental impact of Northern America Free Trade Agreement (NAFTA) on environment. They reported that trade openness (globalization) affects environmental degradation via scale effect keeping composition effect and technique effect constant. Similarly, Dinda [22] claimed that environmental degradation increases as scale effect dominates the composition effect and technique effect and same conclusion is drawn by Shahbaz et al. [23] that trade openness declines CO_2 emissions in case of Pakistan. On the contrary, Wheeler [24] noted that globalization reduces environmental degradation due to the investment in energy-efficient technologies for production. Copeland and Taylor [25] reported that globalization facilitates transfer pollution intensive technology to countries where environmental regulation are weak (in developing economies). In such circumstances, developed countries attain benefits from trade openness at the cost of environment in developing economies. Copeland and Taylor [26] pointed that trade depends upon the relative abundance of factor endowment in each country and therefore, comparative advantage of trade also affects environmental quality depending upon trade and environmental policy in the country. Birdsall and Wheeler [27], Lee and Roland-Host, [28], Jones and Rodolfo [29] opined that environmental degradation is not the main cause of trade openness. Similarly, Antweiler et al. [30] and Liddle [31] pointed out that trade openness improves environmental quality via technique effect. Environmental regulations become strict as income increases and the adoption of energy-efficient technologies are encouraged to save environment from degradation. In case of China, Dean [32] reported that trade openness deteriorates environmental quality via improved terms of trade, however, rise in income saves environment from degradation. Magani [33] used data of 63 developed and developing economies to examine the effect of trade openness on energy emissions. The results showed that a 0.58% carbon emission is linked with a 1% increase in trade. Similarly, McAusland [34] reported that trade affects environment significantly and same view is confirmed by Frankel [35].

3. The data, modeling and estimation strategy

3.1. The data and modeling

We have used data of energy intensity per capita, CO_2 emissions per capita, real GDP per capita and globalization index to probe the existence of environmental Kuznets curve (EKC) in case of Turkey. The data on energy consumption (kilotons of oil equivalent), CO_2 emissions (metric tons) and real GDP (Turkish currency) has been attained from world development indicators (CD-OM, 2012). The series population is used to convert all series into per capita. The data on KOF globalization index is borrowed from Dreher [36]. The globalization index is constructed from three sub-indices (social, economic and political globalization).[2] The study covers the period of 1970–2010. The general functional form of our model is given in the as following equation:

$$\Delta C_t = f(E_t,\ Y_t,\ Y_t^2,\ G_t) \tag{1}$$

We have transformed all the variables into natural logarithm following Shahbaz et al. [23,37]. The empirical form of our model is constructed as follows:

$$\ln C_t = \alpha_1 + \alpha_E \ln E_t + \alpha_Y \ln Y_t + \alpha_{Y^2} \ln Y_t^2 + \alpha_G \ln G_t + \mu_t \tag{2}$$

where $\ln C_t$ is natural log of CO_2 emissions per capita, natural log energy intensity per capita is indicated by $\ln E_t$, $\ln Y_t$ ($\ln Y_t^2$) is the natural log of real GDP per capita (square of real GDP per capita) and $\ln G_t$ is for natural log of KOF index of globalization. μ_t is the error term assumed to be having normal distribution with zero mean and predictable variance. We expect that impact of energy consumption on CO_2 emissions and $\alpha_E > 0$. The relationship between economic growth and CO_2 emissions inverted U-shaped if $\alpha_Y > 0$ and $\alpha_{Y^2} < 0$ otherwise U-shaped if $\alpha_Y < 0$ and $\alpha_{Y^2} > 0$. $\alpha_G < 0$ if energy-efficient technology via foreign direct investment and trade is encouraged for domestic production otherwise $\alpha_G > 0$.

[2] See in details http://globalization.kof.ethz.ch/.

3.2. Zivot–Andrews unit root test

Numerous unit root tests are available to test the stationarity properties of the variables including ADF by Dickey and Fuller [38], P–P by Philips and Perron [39], KPSS by Kwiatkowski et al. [40], DF–GLS by Elliott et al. [41] and Ng–Perron by Ng–Perron [42]. These tests provide biased and spurious results due to non-availability of information about structural break points in series. In doing so, Zivot–Andrews [2] developed three models to test the stationarity properties of the variables in the presence of structural break point in the series: (i) this model allows a one-time change in variables at level form, (ii) this model permits a one-time change in the slope of the trend component i.e. function and (iii) model has one-time change both in intercept and trend function of the variables to be used for empirical analysis. Zivot–Andrews [2] followed three models to validate the hypothesis of one-time structural break in the series as follows:

$$\Delta x_t = a + ax_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{2}$$

$$\Delta x_t = b + bx_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{3}$$

$$\Delta x_t = c + cx_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{4}$$

where dummy variable is indicated by DU_t showing mean shift occurred at each point with time break while trend shift variables is show by DT_t.[3] So,

$$DU_t = \begin{cases} 1 & \text{if} \quad t > TB \\ 0 & \text{if} \quad t < TB \end{cases} \quad \text{and} \quad DU_t = \begin{cases} t-TB & \text{if} \quad t > TB \\ 0 & \text{if} \quad t < TB \end{cases}$$

The null hypothesis of unit root break date is $c=0$ which indicates that series is not stationary with a drift not having information about structural break point while $c<0$ hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot–Andrews unit root test fixes all points as potential for possible time break and estimates through regression for all possible break points successively. Then, this unit root test selects that time break which decreases one-sided t-statistic to test $\hat{c}(=c-1)=1$. Zivot–Andrews report that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where end points of sample period are excluded. Further, Zivot–Andrews suggested the trimming regions i.e. (0.15T, 0.85T).

3.3. The ARDL cointegration

We employ the autoregressive distributed lag (ARDL) bounds testing approach to cointegration developed by Pesaran et al. [44] to explore the existence of long run relationship between economic growth, energy intensity, globalization and CO_2 emissions in the presence of structural break. This approach has multiple econometric advantages. The bounds testing approach is applicable irrespective of whether variables are $I(0)$ or $I(1)$. Moreover, a dynamic unrestricted error correction model (UECM) can be derived from the ARDL bounds testing through a simple linear transformation. The UECM integrates the short run dynamics with the long run equilibrium without losing any long run information. The UECM is expressed as follows:

$$\begin{aligned}\Delta \ln C_t = {} & \alpha_1 + \alpha_T T + \alpha_C \ln C_{t-1} + \alpha_E \ln E_{t-1} + \alpha_Y \ln Y_{t-1} \\ & + \alpha_{Y^2} \ln Y^2_{t-1} + \alpha_G \ln G_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln C_{t-i} \\ & + \sum_{j=1}^{p} \alpha_j \Delta \ln E_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta \ln Y^2_{t-l} \\ & + \sum_{m=0}^{t} \alpha_m \Delta \ln G_{t-m} + \alpha_D D_1 + \mu_{2t}\end{aligned} \tag{9}$$

$$\begin{aligned}\Delta \ln E_t = {} & \alpha_1 + \alpha_T T + \alpha_C \ln C_{t-1} + \alpha_E \ln E_{t-1} + \alpha_Y \ln Y_{t-1} \\ & + \alpha_{Y^2} \ln Y^2_{t-1} + \alpha_G \ln G_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln E_{t-i} \\ & + \sum_{j=1}^{q} \alpha_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta \ln Y^2_{t-l} \\ & + \sum_{m=0}^{t} \alpha_m \Delta \ln G_{t-m} + \alpha_D D_2 + \mu_{2t}\end{aligned} \tag{10}$$

$$\begin{aligned}\Delta \ln Y_t = {} & \alpha_1 + \alpha_T T + \alpha_C \ln C_{t-1} + \alpha_E \ln E_{t-1} + \alpha_Y \ln Y_{t-1} \\ & + \alpha_{Y^2} \ln Y^2_{t-1} + \alpha_G \ln G_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln Y_{t-i} \\ & + \sum_{j=1}^{q} \beta_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln Y^2_{t-l} \\ & + \sum_{m=0}^{t} \beta_m \Delta \ln G_{t-m} + \beta_D D_3 + \mu_{3t}\end{aligned} \tag{11}$$

$$\begin{aligned}\Delta \ln Y^2_t = {} & \alpha_1 + \alpha_T T + \alpha_C \ln C_{t-1} + \alpha_E \ln E_{t-1} + \alpha_Y \ln Y_{t-1} \\ & + \alpha_{Y^2} \ln Y^2_{t-1} + \alpha_G \ln G_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta \ln Y^2_{t-1} \\ & + \sum_{j=0}^{q} \vartheta_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \vartheta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \vartheta_l \Delta \ln Y_{t-l} \\ & + \sum_{m=0}^{t} \vartheta_m \Delta \ln G_{t-l} + \vartheta_D D_4 + \mu_{4t}\end{aligned} \tag{12}$$

$$\begin{aligned}\Delta \ln G_t = {} & \alpha_1 + \alpha_T T + \alpha_C \ln C_{t-1} + \alpha_E \ln E_{t-1} + \alpha_Y \ln Y_{t-1} \\ & + \alpha_{Y^2} \ln Y^2_{t-1} + \alpha_G \ln G_{t-1} + \sum_{i=1}^{p} \rho_i \Delta \ln G_{t-i} \\ & + \sum_{j=0}^{q} \rho_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \rho_k \Delta \ln E_{t-k} \\ & + \sum_{l=0}^{s} \rho_l \Delta \ln Y_{t-1} + \sum_{m=0}^{t} \rho_m \Delta \ln Y^2_{t-m} + \vartheta_D D_5 + \mu_{5t}\end{aligned} \tag{13}$$

where Δ is the first difference operator, D is dummy for structural break point and $\mu_t$is error term assumed to be independently and identically distributed. The optimal lag structure of the first differenced regression is selected by the Akaike information criteria (AIC). Pesaran et al. [44] suggests F-test for joint significance of the coefficients of the lagged level of variables. For example, the null hypothesis of no long run relationship between the variables is $H_0: \alpha_C = \alpha_E = \alpha_Y = \alpha_{Y^2} = \alpha_G = 0$ against the alternative hypothesis of cointegration $H_a: \alpha_C \neq \alpha_E \neq \alpha_Y \neq \alpha_{Y^2} \neq \alpha_G \neq 0$. Pesaran et al. [44] computed two sets of critical value (lower and upper critical bounds) for a given significance level. Lower critical bound is applied if the regressors are $I(0)$ and the upper critical bound is used for $I(1)$. If the F-statistic exceeds the upper critical value, we conclude in favor of a long run relationship. If the F-statistic falls below the lower critical bound, we cannot reject the null hypothesis of no cointegration. However, if the F-statistic lies between the lower and upper critical bounds, inference would be inconclusive. When the order of integration of all the series is known to be $I(1)$ then decision is made based on the upper critical bound. Similarly, if all the series are $I(0)$, then the decision is made based on the lower critical bound. To check the robustness of the ARDL model, we apply diagnostic tests. The diagnostics tests check normality of error term, serial

[3] We used model-4 for empirical estimations following Sen [43].

Table 2
Descriptive statistics and correlation matrix.

Variables	$\ln C_t$	$\ln Y_t$	$\ln E_t$	$\ln G_t$
Mean	0.8961	6.7912	6.7916	3.8872
Median	0.9773	6.8019	6.8225	3.8954
Maximum	1.5838	7.2413	7.2224	4.2481
Minimum	0.2495	6.3641	6.2651	3.5562
Std. dev.	0.3441	0.2609	0.2560	0.2368
Skewness	−0.0055	0.1553	−0.1652	−0.1119
Kurtosis	2.0783	1.8726	1.8994	1.3856
Jarque–Bera	1.4160	2.2789	2.2007	4.4271
Probability	0.4926	0.3199	0.3327	0.1093
$\ln C_t$	1.0000			
$\ln Y_t$	0.6083	1.0000		
$\ln E_t$	0.7010	0.6901	1.0000	
$\ln G_t$	−0.3353	−0.0666	−0.0710	1.0000

correlation, autoregressive conditional heteroscedasticity, white heteroscedasticity and the functional form of empirical model.

3.4. The VECM Granger causality

After examining the long run relationship between the variables, we use the Granger causality test to determine the causality between the variables. In case of cointegration between the series, the vector error correction method (VECM) can be developed as followings:

$$\begin{bmatrix}\Delta\ln C_t\\ \Delta\ln E_t\\ \Delta\ln Y_t\\ \Delta\ln Y_t^2\\ \Delta\ln G_t\end{bmatrix}=\begin{bmatrix}b_1\\ b_2\\ b_3\\ b_4\end{bmatrix}+\begin{bmatrix}B_{11,1}B_{12,1}B_{13,1}B_{14,1}B_{12,1}\\ B_{21,1}B_{22,1}B_{23,1}B_{24,1}B_{25,1}\\ B_{31,1}B_{32,1}B_{33,1}B_{34,1}B_{35,1}\\ B_{41,1}B_{42,1}B_{43,1}B_{44,1}B_{45,1}\\ B_{51,1}B_{52,1}B_{53,1}B_{54,1}B_{55,1}\end{bmatrix}\times\begin{bmatrix}\Delta\ln C_{t-1}\\ \Delta\ln E_{t-1}\\ \Delta\ln Y_{t-1}\\ \Delta\ln Y_{t-1}^2\\ \Delta\ln G_{t-1}\end{bmatrix}$$
$$+\ldots+\begin{bmatrix}B_{11,m}B_{12,m}B_{13,m}B_{14,m}B_{15,m}\\ B_{21,m}B_{22,m}B_{23,m}B_{24,m}B_{25,m}\\ B_{31,m}B_{32,m}B_{33,m}B_{34,m}B_{35,m}\\ B_{41,m}B_{42,m}B_{43,m}B_{44,m}B_{45,m}\\ B_{51,m}B_{52,m}B_{53,m}B_{54,m}B_{55,m}\end{bmatrix}$$
$$\times\begin{bmatrix}\Delta\ln C_{t-1}\\ \Delta\ln E_{t-1}\\ \Delta\ln Y_{t-1}\\ \Delta\ln Y_{t-1}^2\\ \Delta\ln G_{t-1}\end{bmatrix}+\begin{bmatrix}\zeta_1\\ \zeta_2\\ \zeta_3\\ \zeta_4\\ \zeta_5\end{bmatrix}\times(ECM_{t-1})+\begin{bmatrix}\mu_{1t}\\ \mu_{2t}\\ \mu_{3t}\\ \mu_{4t}\\ \mu_{5t}\end{bmatrix} \tag{14}$$

where difference operator is $(1-L)$ and ECM_{t-1} is the lagged error correction term, generated from the long run association. The long run causality is found by the significance of coefficient of lagged error correction term using t-test statistic. The existence of a significant relationship in first differences of the variables provides evidence on the direction of short run causality. The joint χ^2 statistic for the first differenced lagged independent variables is used to test the direction of joint long-and-short runs causality between the variables. For example, $B_{12,i}\neq 0\forall_i$ shows that energy intensity Granger causes CO_2 emissions and energy intensity is Granger cause of CO_2 emissions if $B_{21,i}\neq 0\forall_i$.

4. Results discussion

Descriptive statistics and correlation matrix are presented in Table 2. Based on Jarque–Bera test statistics, our results indicate that all the series are normally distributed having zero mean while variance is constant. This leads us to peruse for further analysis. The correlation matrix reveals a positive association between the underlying variables. For instance, economic growth is positively correlated with CO_2 emissions and same is true between energy intensity and CO_2 emissions. A positive and high correlation is found between energy intensity and economic growth. Globalization is inversely correlated with CO_2 emissions, economic growth and energy intensity.

Table 3
Zivot–Andrews structural break trended unit root test.

Variable	At level		At 1st difference	
	t-Statistic	Time break	t-Statistic	Time break
$\ln C_t$	−3.768 (1)	2001	−6.544 (1)*	1998
$\ln Y_t$	−4.210 (2)	1986	−6.559 (0)*	2004
$\ln Y_t^2$	−4.108 (2)	1986	−6.684 (0)*	2004
$\ln E_t$	−3.676 (1)	1986	−6.483 (0)*	2006
$\ln G_t$	−2.927(0)	2005	−8.112 (1)*	1992

* Significant at 1% level. Lag order is shown in parenthesis.

There is a need to test the order of integration of the variables before applying the ARDL bounds testing to investigate long run relationship. Although, the ARDL bounds testing approach assumes that the variables must be stationary at $I(0)$ or $I(1)$ or $I(0)/I(1)$. The process to compute F-statistic becomes invalid if any series is found to be stationary at $I(2)$. So just to ensure that none of the variables is integrated beyond mentioned order of integration, we have applied ADF unit root test. Our results of ADF and PP tests confined that none of the variables is stationary at level with intercept and trend. All the series are found to be integrated at $I(1)$.[4] The results of these may be biased and unreliable because both unit root tests ignore the role of structural break stemming in the series. The appropriate information about structural break arising in the series would be helpful to policy makers in articulating a comprehensive energy, economic, trade and environmental policy to sustain long run economic growth. This issue has been resolved by applying Zivot–Andrews unit root test accommodating the information about single unknown structural break.

The results shown in Table 3 reported that CO_2 emissions, economic growth, energy intensity and globalization have unit root problem at level but all the series are stationary at 1st difference with intercept and trend. The same level of integrating properties of the variables intends to apply the ARDL bounds testing approach to cointegration to examine the long run relationship between economic growth, energy intensity, globalization and CO_2 emissions over the period of 1971–2010 in case of Turkey. The two step ARDL procedure requires appropriate lag order of the variable to calculate F-statistic. We have used numerous lag length criterions and results are reported in Table 4. We lag selection is based on Akaike information criteria (AIC). Lütkepohl [45] argued that AIC has superior power properties for small sample data compared to other lag length criterions. The results reported in Table 4 noted that lag 2 is sufficient for such small sample data having only 40 observations (see third row of Table 4).

The second step deals with the calculation of F-statistic to confirm whether cointegration between the variables i.e. economic growth, energy intensity, globalization and CO_2emissions exists or not. Table 4 presents the results of the ARDL bounds testing analysis. Our empirical evidence reveals that upper critical bound is less than our calculated F-statistic when we used CO_2 emissions, real GDP per capita (square of real GDP per capita) and energy intensity as dependent variables. Our F-statistics 11.656, 8.941 (8.005) and 12.382 are statistically significant at 1(5)% level

[4] Results are available upon request from authors.

Table 4
Results of ARDL cointegration test.

Estimated models	$C_t = f(Y_t, Y_t^2, E_t, G_t)$	$Y_t = f(C_t, Y_t^2, E_t, G_t)$	$Y_t^2 = f(C_t, Y_t, E_t, G_t)$	$E_t = f(C_t, Y_t, Y_t^2, G_t)$	$G_t = f(C_t, Y_t, Y_t^2, G_t)$
F-statistics	11.656*	8.941**	8.005**	12.382*	1.3342
Lag order	2, 2, 2, 2, 2	2, 2, 2, 2, 1	2, 2, 2, 2, 1	2, 2, 1, 2, 1	2, 2, 2, 2, 2
Critical values	1% level	5% level	10% level[a]		
Lower bounds	10.150	7.135	5.950		
Upper bounds	11.130	7.980	6.680		
Diagnostic tests					
R^2	0.9017	0.9997	0.9997	0.9819	0.8018
Adj-R^2	0.7542	0.9994	0.9994	0.9590	0.6037
Durbin–Watson	2.0578	1.9480	1.9572	1.8956	2.3233

[a] Critical values bounds are from [47] with unrestricted intercept and unrestricted trend.
* Significance at 1% level.
** Significance at 5% level.

Table 5
Results of Johansen cointegration test.

Hypothesis	Trace statistic	Maximum eigen value
$R = 0$	95.3434*	69.8188*
$R \le 1$	49.7529**	47.8561**
$R \le 2$	19.3135	29.7970
$R \le 3$	6.9000	15.4947
$R \le 4$	1.3126	3.8414

* Significant at 1% level.
** Significant at 5% level.

of significance. This implies that we have four cointegrating vectors confirming long run relationship between economic growth, energy intensity, globalization and CO_2 emissions over the period of 1971–2010.

The robustness of long run results is investigated by applying Johansen and Juselies [46] cointegration approach and results are reported in Table 5. The results indicate two cointegrating vectors again confirming cointegration between the variables.

The problem with results of the ARDL bounds testing developed by Pesaran et al. [44] and Johansen and Juselies [46] is that they do not have information about structural break stemming in the series. Therefore in order to overcome this problem we have applied Gregory–Hansen [48] cointegration approach accommodating single structural break pointed out by Z–A unit root test. This test provides consistent and reliable empirical evidence as compared to other traditional cointegration tests [49]. Table 6 reports the results of Gregory–Hansen cointegration and we find cointegrating single vector once we use economic growth, globalization and CO_2 emissions as forcing variables. This implies that cointegration is found in energy intensity equation after allowing for structural break in 1986. This break point is due to the usage of more coal instead of oil due to the oil crisis of 1970s. Overall, we find that long run results are robust.

Table 7 deals with the long-run marginal impacts of economic growth, energy intensity and globalization on CO_2 emissions. The results expose that linear term of real income per capita has positive impact on CO_2 emissions and whereas negative effect of square term of real income per capita on CO_2 emissions is reported which is statistically significant at 5% level of significance. This implies that inverted U-shaped relationship exists between real income per capita (square of real GDP per capita) and CO_2 emissions. The estimates of linear and nonlinear terms are 7.3502 and −0.4336. This empirical exercise validates the existence of environmental Kuznets curve (EKC). This shows that a 1% increase in real income per capita is linked with 7.3502% increase in CO_2 emissions and inverse effect of squared term of real income per capita indicates the delinking point of CO_2 emissions i.e.−0.4332, once an economy achieves threshold level of real income per capita. This justifies for the support of EKC which reveals that economic growth increases CO_2 emissions initially and improves the environmental quality once economy is achieves threshold level of income per capita. A positive relationship is found between energy consumption and CO_2 emissions and it is statistically significant at 5% level. All else is remaining the same, a 1% increase in energy consumption raises CO_2 emissions by 0.7155% which shows that energy intensity is a major contributor to CO_2 emissions. Globalization has inverse impact on CO_2 emissions and is statistically significant at 10% level of significance. The results report that a 0.1950% decline in CO_2 emissions is due to 1% increase in globalization by keeping other things constant.

The short run results are illustrated in lower part of Table 7. The results intend that linear and nonlinear terms of real GDP per capita have positive and negative signs (inverted-U shaped relation) on CO_2 emissions and are statistically significant at 1% level of significance. The impact of energy intensity is positive on CO_2 emissions and it is statistically significant at 1% significance level. Globalization has inverse impact on CO_2 emissions at 10% level of significance. The coefficient of ECM_{t-1} has negative sign and significant at 10% level of significance. The significance of lagged error term corroborates the established long run association between the variables. Furthermore, the negative and significant value of ECM_{t-1} implies that any change in CO_2 emissions from short run towards long span of time is corrected by 27.54% every year. Sensitivity analysis indicates that short run model passes all diagnostic tests i.e. LM test for serial correlation, ARCH test, normality test of residual term, white heteroscedasticity and model specification successfully. The results are shown in lower segment of Table 7. It is found that short run model does not show any evidence of non-normality of residual term and implies that error term is normally distributed with zero mean and covariance. The serial correlation does not exist between error term and CO_2 emissions. There is no autoregressive conditional heteroscedasticity and the same inference is drawn about white heteroscedasticity. The model is well specified proved by Ramsey RESET test. The stability of the ARDL bounds testing approach estimates is investigated by applying the CUSUM and CUSUMsq tests. The results are shown in Figs. 1 and 2. The plots of the CUSUM statistics are well within the critical bounds.

The plots of the CUSUMsq test are not within the critical bounds. Furthermore, we apply Chow forecast test to examine the significance structural breaks in an economy for the period of 2000–2010. In this study, *F*-statistic computed in Table 8 suggests that no significant structural break exists in case of Turkey during the sample period. The Chow forecast test is more reliable and

Table 6
Gregory–Hansen structural break cointegration test.

Model	$T_C(C/Y_t,\ Y_t^2,\ E_t,\ G_t)$	$T_Y(Y_t/C_t,\ Y_t^2,\ E_t,\ G_t)$	$T_{Y^2}(Y_t^2/C_t,\ Y_t,\ E_t,\ G_t)$	$T_E(E_t/C_t,\ Y_t,\ Y_t^2,\ G_t)$	$T_G(G_t/C_t,\ Y_t,\ Y_t^2,\ E_t)$
ADF-test	−3.0963	−3.8733	−3.7339	−4.9861**	−3.5329
Break year	2001	1986	1986	1986	2005
Prob. values	0.0028	0.0003	0.0004	0.0006	0.0008

The ADF statistics show the Gregory–Hansen tests of cointegration with an endogenous break in the intercept. Critical values for the ADF test at 1%, 5% and 10% are −5.13, −4.61 and −4.34 respectively.

** Significance at 5% level.

Table 7
Long-and-short run analysis.

Dependent variable = ln C_t			
Long run results			
Variable	Coefficient	Std. error	*t*-Statistic
Constant	−28.2399*	9.4667	−2.9830
$\ln Y_t$	7.3502**	2.8005	2.6245
$\ln Y_t^2$	−0.4336**	0.2030	−2.1362
$\ln E_t$	0.7155**	0.3162	2.2627
$\ln G_t$	−0.1950***	0.1149	−1.6968
Short run results			
Constant	0.0130	0.0104	1.2448
$\ln Y_t$	10.3856*	3.3239	3.1245
$\ln Y_t^2$	−0.7473*	0.2426	−3.0801
$\ln E_t$	0.7696*	0.1913	4.0223
$\ln G_t$	−0.2952***	0.1686	−1.7504
ECM_{t-1}	−0.2754***	0.1578	−1.7452
Diagnostic tests			
Test	*F*-statistic	Prob. value	
$\chi^2 NORMAL$	3.6450	0.1616	
$\chi^2 SERIAL$	0.9255	0.3434	
$\chi^2 ARCH$	0.9063	0.3476	
$\chi^2 WHITE$	0.7055	0.7110	
$\chi^2 RAMSEY$	2.6867	0.1112	

* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.

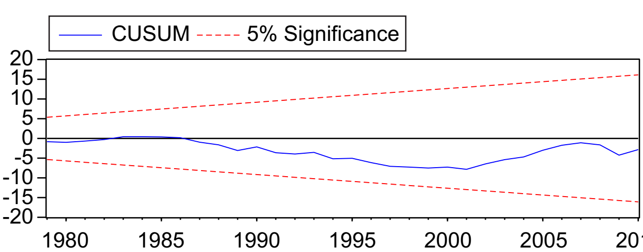

Fig. 1. Plot of cumulative sum of recursive residuals. The straight lines represent critical bounds at 5% significance level.

preferable than graphs [50]. This confirms that the ARDL estimates are reliable and efficient.

The presence of cointegration among the variables implies that causality relation must exist at least from one side. The directional relationship between energy intensity, economic growth, globalization and CO_2 emissions will provide help in articulating comprehensive policy to sustain economic growth by controlling environment from degradation and utilizing energy efficient technologies imported from advanced countries. We applied Granger causality test within the VECM framework to detect the causality between the variables. Table 9 reports the results of the VECM Granger causality analysis. The long run causality is captured by a significant *t*-test on a negative coefficient of the lagged

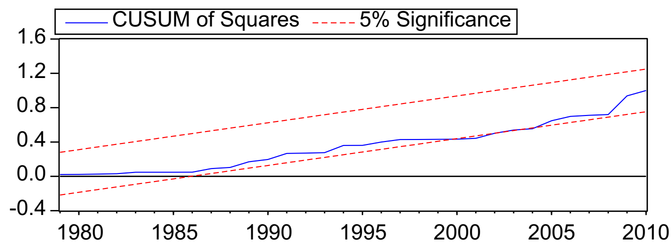

Fig. 2. Plot of cumulative sum of squares of recursive residuals. The straight lines represent critical bounds at 5% significance level.

Table 8
Chow forecast test.

Chow forecast test: forecast from 2000 to 2010			
F-statistic	1.5110	Probability	0.2090
Log likelihood ratio	13.7608	Probability	0.0556

error-correction term ECM_{t-1}. The jointly significant LR test on the lagged explanatory variables shows short-run causality.

Table 9 reveals that the estimates of ECM_{t-1} are having negative signs and statistically significant in all the VECMs. The significance of lagged error term shows speed of adjustment from short run toward long run equilibrium path in the equation of energy consumption (−0.7311), economic growth (−0.4990, −0.4955) as well as CO_2 emissions (−0.3801). This implies that the VECM equation of energy intensity has high speed of adjustment (−0.7311) as compared to economic growth (−0.4990, −0.4955) and CO_2 emissions (−0.3801) the VECMs.

The long run causality result reported that the feedback effect is found between economic growth and CO_2 emissions. This implies that Turkey is achieving economic growth at the cost of environment. The bidirectional causality is found between energy intensity and CO_2 emissions. This suggests adopting energy-efficient technology to enhance production which emits less CO_2 emissions. The feedback effect also exists between economic growth and energy intensity.

This reveals that energy is an important stimulant like other factor of production and reduction in energy consumption would retard economic growth. This finding supports for energy exploration policies to sustain economic growth for long run. Globalization Granger causes economic growth, energy intensity and CO_2 emissions validating the globalization-led growth, globalization-led energy and globalization-led CO_2 emissions hypotheses.

The results of short run causality are very interesting. The neutral effect is found between CO_2 emissions and globalization and, the same is true for energy intensity and globalization. Economic growth Granger causes CO_2 emissions. The feedback effect exists between energy intensity and CO_2 emissions. There is no causality between energy intensity and economic growth.

Table 9
VECM granger causality analysis.

Dependent variable	Direction of causality										
	Short run					Long run	Joint long-and-short runs causality				
	$\Delta \ln C_{t-1}$	$\Delta \ln Y_{t-1}$	$\Delta \ln Y^2_{t-1}$	$\Delta \ln E_{t-1}$	$\Delta \ln G_{t-1}$	ECT_{t-1}	$\Delta \ln C_{t-1}$, ECT_{t-1}	$\Delta \ln Y_{t-1}$, ECT_{t-1}	$\Delta \ln Y^2_{t-1}$, ECT_{t-1}	$\Delta \ln E_{t-1}$, ECT_{t-1}	$\Delta \ln G_{t-1}$, ECT_{t-1}
$\Delta \ln C_t$	–	3.0346*** [0.0672]	2.9838*** [0.0688]	14.2094* [0.0001]	0.3061 [0.7390]	−0.3801*** [−1.7435]	–	2.9935** [0.0449]	2.9572** [0.0517]	14.7276* [0.0000]	2.4427*** [0.0877]
$\Delta \ln Y_t$	0.7304 [0.4913]	– –	78.5723* [0.0000]	1.0836 [0.3532]	2.8899*** [0.0736]	−0.4990* [−4.1581]	6.9671* [0.0014]	– –	58.0545* [0.0000]	6.0488* [0.0029]	6.2609* [0.0024]
$\Delta \ln Y^2_t$	0.6585 [0.5282]	82.1544* [0.0000]	– –	0.9978 [0.3824]	3.1674*** [0.0587]	−0.4955* [−4.2409]	7.0971* [0.0012]	58.9627* [0.0000]	– –	6.2364* [0.0025]	6.4747* [0.0020]
$\Delta \ln E_t$	8.7686* [0.0012]	0.2828 [0.7558]	0.2198 [0.8041]	– –	0.5230 [0.5986]	−0.7311*** [−1.8901]	7.2650* [0.0010]	3.2025 [0.0213]	3.2027** [0.0212]	– –	4.4582** [0.0114]
$\Delta \ln G_t$	1.2117 [0.3139]	1.3052 [0.2883]	1.1836 [0.3221]	0.0566 [0.9450]	–	–	–	–	–	–	–

* Significance at 1% level.
** Significance at 5% level.
*** Significance at 10% level.

The joint causality results are also reported in Table 9 validating our long-and-short runs findings.

5. Conclusion and policy implications

This paper probes the relationship between CO_2 emissions and economic growth by incorporating energy intensity and globalization as potential determinants of economic growth and CO_2 emissions in case of Turkey using annual data over the period of 1970–2010. We have applied cointegration approaches to test the robustness of long run relationship between the variables is in the presence of structural breaks. The VECM Granger causality approach has been applied to examine the causal relationship between economic growth, energy intensity, globalization and CO_2 emissions.

Our empirical exercise confirms the existence of cointegration in the presence of structural breaks in the series. Moreover, inverted U-shaped relationship is found between economic growth and CO_2 emissions i.e. Environmental Kuznets curve (EKC). Thus, beyond a threshold level of real GDP per capita, any increase in real GDP per capita is likely to reduce the carbon emissions per capita in Turkey.

Energy intensity increases CO_2 emissions and is a major contributor to energy emissions. Globalization seems to lower CO_2 emissions. We find feedback effect between economic growth and CO_2 emissions. The bidirectional causality is found between energy intensity and CO_2 emissions and same is true for energy intensity and economic growth. Economic growth, energy intensity and CO_2 emissions Granger cause globalization.

Turkey is a candidate for full membership to the European Union (EU) and signed Kyoto Protocol to introduce its national plan on climate change and global warming along with specific emission targets and the associated abatement policies. Thus, numerous measures had been taken in last few years. However, these measures are not adequate for reducing environmental pollution without any sacrifices on the Turkish economic growth. To decrease carbon emissions and energy import related current account deficit of Turkey, the usage of alternative energy sources (renewable energy sources) like solar, wind, geothermal sources and bio-diesel fuel should be increased and green investment technologies should be supported.

For future research, renewable and non-renewable energy sources of energy can be incorporated in neo-classical production to examine the relationship between energy consumption and economic growth following Shahbaz et al. [51] and Leitão [52] by incorporating the globalization. Globalization is a potential determinant of economic growth and energy consumption. There is need of empirical investigation of sectoral environmental Kuznets's curve in Turkey to improve environmental quality and for sustainable economic development in long run. The sectoral analysis of EKC would be helpful for designing a comprehensive growth, energy and environmental policy to maintain living standard of Turkish people.

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